

brought about in this particular case are of interest. It could scarcely be the result of a reduction in temperature due to the stirring, *per se*, of the air by the propeller. An increase in the moisture content of the air is probably involved. Of the two following suggestions as to the origin of the cloud the first, and probably the correct one, was made by Prof. Humphreys:

The end products of complete combustion of gasoline are water vapor and carbon dioxide, and it is found that if the water vapor were condensed, there would result a little more than 1 gallon of water per gallon of gasoline consumed. It was found by Wells and Thuras, in studying the fogs off the Newfoundland coast (see *U. S. Coast Guard, Bull.* 5, 1916) that there were 1,200 water droplets of diameter 0.01 mm. in a cubic centimeter of air in a dense fog. If we assume that an airplane travels 3 miles on a gallon of gasoline (approximately the figure given by the Aerial Mail Service) it is possible to show that if only a small part—a fourth or fifth—of the water vapor were condensed, there would be abundant cloud to produce the effect observed at the Argonne Battle. It should be stated, however, that this water vapor would have to be discharged into air which was very cold and nearly saturated. This seems to be the correct explanation, and is substantiated by scientists at the Bureau of Standards, who say that they have actually observed this cloud behind airplanes and automobiles. The Bureau of Standards is working on a device for condensing and using this water aboard dirigibles as ballast.

The second suggestion, by the writer of this note, is in harmony with experimental results, though whether the necessary conditions can exist in the free air is a question. It is suggested that it may be possible for supersaturation to occur in the atmosphere and for shock of some sort to induce condensation in air in which this unstable condition exists. Color is perhaps lent to this speculation by the facts that condensation has been induced, experimentally, in supersaturated air, by shock, and that the supercooling of water droplets is a recognized process in the free air. Mr. K. C. M. Douglas has shown¹ "that clouds consisting of supercooled water droplets may exist more than 10,000 feet above clouds consisting of ice crystals," and at temperatures at least 43° F. below the freezing point of water, and that shock of impact with his plane caused the instant freezing of the droplets. In the case of the Argonne Battle cloud, the question is therefore raised as to whether supersaturation can occur in the free air, and whether atmospheric vibrations set up by the exhausts from the engines would be a sufficient cause of condensation in such air. If such were the case, the volume of air involved would doubtless be great enough to furnish water vapor sufficient to form a visible cloud.

551.57 (048)

FROST SUPERSATURATION (FROSTÜBERSÄTTIGUNG) AND CIRRUS.

By ALFRED WEGENER.

[Abstracted from *Meteorologische Zeitschrift*, Jan.-Feb., 1920, pp. 8-12.]

It is possible to find conditions of vapor pressure and temperature, in which the space over ice is saturated, but over under-cooled water at the same temperature it is not saturated. The author has given this condition the name *Frostübersättigung*, or frost supersaturation. There exists a point, known as a triple point, at which water, ice, and undercooled water may exist side by side. The coordinates of this point are e (vapor pressure) = 4.57 mm., and t (temperature) = +0.0075° C. At temperatures below this point evaporation will cease to take place from an ice surface at a slightly lower vapor pressure than from an (undercooled) water surface at the same

temperature. In other words, over a small range of vapor pressure condensation may be occurring on ice at the same time that water at the same temperature is evaporating. The point of maximum difference of vapor pressure, amounting to 0.2 mm., occurs at a temperature of -11.4° C.

Some of the consequences of this physical relation are pointed out. It has often been observed in free-balloon ascents that, above the 0° C. isotherm, undercooled water droplets and snow crystals may simultaneously occur. But the water droplets are evaporating and the snow crystals are growing larger, with the result that water eventually disappears. This is the spectacle afforded by the streaks of falling snow above which the mother cloud has entirely evaporated.

Many observations have been made in Greenland of cases in which the air has been supersaturated with respect to ice but not to water. The result has been that large crystals of ice have been seen to form on the snow. In addition, occasionally with a higher relative humidity, fog has formed after the ice crystals have appeared. In the case where this crystal-forming stage has been followed by a rise in temperature and a consequent fall in humidity, the ice crystals have disappeared. This phenomenon can occur in clear weather.¹

The author gives other examples: On a day with a temperature of -40° C., a cloud 3 km. in length was seen in Greenland, stretching away from a chimney. During three airplane flights over Munich at a height of 9 km. a cloud 50 km. in length was formed. That it was composed of ice crystals was proved by the fact that the 22° halo was observed. This cloud the author attributes to the nuclei furnished by the motor exhaust.² A horse, warm from running over the ice, on a cold day in Greenland, was accompanied by a cloud 50 meters in height formed from its breath. Von Hann gives a similar case regarding a herd of reindeer. The human breath also has been seen to transform itself into small clouds of ice needles. These are also attributed to nuclei discharged into the air.³

The condition of frost supersaturation may be responsible for the apparent self-sustaining nature of cirrus wisps. It may be that the cirrus particles, forming at high elevations fall into supersaturated layers. The crystals of the cirrus act as nuclei for growth, and the consequence is that the layer changes from a state of supersaturation to one of saturation and the cloud appears to spread out and become heavier merely by virtue of the ice formed upon the falling crystal.—C. L. M.

551.510.4 (048) (6)

ON THE FREQUENCY OF FOGS IN THE EASTERN SAHARA.

By J. TILHO.

[Abstracted from *Comptes Rendus*, Paris Acad., June 14, 1920, pp. 1435-1438.]

It has often been observed that during December and January the west coast of Africa, particularly that in the vicinity of the Gulf of Guinea, is visited by northeast winds accompanied by persistent fogs, which seemed to be constituted quite largely by fine dust particles sup-

¹ Such frost can also form when the ice-surface temperature is below the (ice) dew-point of the air—without frost supersaturation in the space above the ice.—Editor.

² Capt. Walter H. Nead in the *American Legion Weekly* of Oct. 22, 1920, relates the formation of long cirrus clouds in the wake of three airplanes in the vicinity of Montfaucon, France, on Oct. 10, 1918. At first the trails were thought to be smoke, but they proved to be too wide for smoke. Their ice-crystal structure became evident when halo phenomena were observed as a result of their presence. Cf. "The Argonne Battle Cloud." This Review, pp. 348-349.—Editor.

³ The moisture without the nuclei discharged would be ample to make such clouds, therefore, the nuclei merely assure the formation of the cloud which would probably form anyway.—Editor.

⁴ Douglas, C. K. M.: Optical phenomena and the composition of clouds. *Jour. Scot. Met. Soc.*, Vol. XVIII, 3d series No. XXXVI, pp. 83-86.

posed to have come from the desert or semidesert regions. Similar fogs have also been observed along the Niger River, in Zinder, and around Lake Chad. While in the Borku Oasis (northeast of Lake Chad) the fogs observed were remarkable for their extreme dryness, as is attested by the following table:

Date of fog and hour of observation.	Temperature.		Relative Humidity.	Wind.	
	Dry-bulb.	Wet-bulb.		Direction.	Speed.
Dec. 4, 1914:	° C.	° C.	Per cent.		Meters per second.
6 a. m.	18.9	9.1	17	NE.	12
12 m.	25.8	12.4	12	NE.	15
9 p. m.	21.5	11.8	24	NE.	12
Dec. 5, 1914:					
6 a. m.	15.3	6.9	19	NE.	18
12 m.	21.0	9.8	13	NE.	22
9 p. m.	18.0	8.9	20	NE.	16

State of the atmosphere: Heavy fog with visibility limited to about 300 to 400 meters.

Owing to the frequency and duration of these dry fogs of the Sahara, they are of importance to aviation. Observations were carefully made from May, 1914, to April, 1917, at Borku, three times a day. The following scale was used in estimating the intensity of fogs:

Heavy fog..... Visibility limited to 0.5 km.
Moderate fog..... Visibility limited to 3 km.
Light fog..... Visibility greater than 3 km.

Distances were estimated in the daytime by certain known groups of palm trees, rocks, etc., while at night they were indirectly estimated by observing the various magnitudes of visible stars. The number of fogs so observed were as follows:

Year and month.	Number of fogs observed.			Total number of observations.	Per cent.
	Heavy.	Moderate.	Light.		
1915, 1916, 1917:					
January.....	10	32	42	273	15.4
February.....	29	20	49	237	19.0
March.....	13	21	34	279	12.2
April.....	24	21	45	245	18.4
1916, 1916:					
May.....	5	13	18	181	10.0
1914, 1915, 1916:					
June.....	22	26	48	269	18.0
July.....	21	17	35	275	13.8
August.....	13	12	25	177	9.0
September.....	1	10	11	261	4.2
October.....	4	2	6	283	2.3
November.....	3	8	8	265	3.0
December.....	16	37	53	276	19.2

It appears from the table that the time of greatest fog frequency is that between the winter and summer solstices, while the northeast winds dominate the region. From August to November, when the west and southwest winds are dominant, there are fewer fogs. The northeast fog-producing winds are persistent and blow with great violence for many days at a time, and generally reach maximum about 10 a. m. and a minimum about sundown.

While it is difficult to estimate the depth of these fogs, it is certain that they are often deeper than the highest rocks at Borku, which extend upward 250 to 300 meters.

As the speed of the wind increases it is observed that the intensity of the fog increases. With winds above 8 or 10 meters per second the fog recorded is usually heavy; below that speed, it is light. As the wind dies down, the dust particles settle out of the air to the ground, and the visibility becomes equal to that in France on the best days, and it is often possible to see from 100 to 120 kilometers.

Sand storms.—These storms are frequently observed with such violence as to quickly bury small objects, such as boxes, camp equipment, etc. Pebbles the size of a hazelnut and minute crystal of quartz serve to make exposure to such a storm very uncomfortable. Static electrical phenomena are frequently observed under such conditions.—C. L. M.

551.578.1 (73)

ON THE DIFFERENCES BETWEEN SUMMER DAYTIME AND NIGHTTIME PRECIPITATION IN THE UNITED STATES.

By W. J. HUMPHREYS.

[Weather Bureau, Washington, D. C., July 10, 1921.]

Several studies have been made of the hourly distribution of the amount of precipitation in many parts of the world, and the results of most of these have been given in Hann's *Lehrbuch der Meteorologie* (3d edition, pp. 338-346). A later paper¹ shows both in tables and by chart (reproduced here as fig. 1) the various percentages of the 24-hour rainfall in different portions of the United States that occur at night during the summer. The inequalities between, the day and night precipitations here shown are both interesting and important, and hence need to be explained.

In most, if not all, parts of this country, as also nearly everywhere else, the day and night distribution of summer rainfall is substantially the same as, and owing to, the corresponding distribution of the thunderstorm. And, since this type of storm is caused by a strong vertical convection of air containing a considerable amount of water vapor, it follows that summer precipitation is divided between day and night in substantially the same proportion as is the strong vertical convection of tolerably humid air.

In the southeastern portion of the United States where the prevailing summer winds are southerly (hence humid) and gentle most of the rainfall of this season is due to heat thunderstorms—that is, local thunderstorms resulting from convection induced by strong surface heating. Hence in this section summer rains are most frequent about mid afternoon.

Similarly, throughout much of the Rocky Mountain and Plateau regions, especially about the chimney-acting peaks and other places favorable to strong updrafts, cumuli and the resulting precipitation are most frequent during summer, in the afternoon, and least frequent at night.

Through the northeastern portion of the United States the typical heat thunderstorm is of secondary importance. Nevertheless, its occurrence there appears still to be often enough to account for the slight excess in that region of the daytime over the nighttime precipitation.

There remain for consideration the regions in which the summer rain is most abundant by night.

One of these regions is the lower Michigan peninsula. Here, as elsewhere, rain at any given place and time is due to clouds that had their inception to the windward. In general, therefore, the rains over the lower Michigan peninsula are from clouds that either originated above or crossed over Lake Michigan. Now, during summer the land areas about this lake, as, in general, about all lakes, commonly are warmer through the day than the surface of the water and cooler at night. Hence, convection over the lake and, consequently, the cloudiness and precipitation to the near leeward—that is, over the lower peninsula—are greatest at night.

¹ Kincer, J. B., MONTHLY WEATHER REV., NOV., 1916, 44; 628-632.